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REPORT NRL-80-C-0238-F

DEMOUNTABLE CONNECTOR FOR SINGLE MODE OPTICAL FIBER

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TRW INC.
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December 1981

Final Report for Period

27 June 1980 - 31 August 1981

prepared for :

NAVAL RESEARCH LABORATORY
4555 Overlook avenue, SW
Washington ,D.C. 20375

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1. REPORT NUMBER NRL-80-C-0238-F	2. GOVT ACCESSION NO. AD-A111229	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Demountable Connector For Single Mode Optical Fiber		5. TYPE OF REPORT & PERIOD COVERED Final Report 27 June 1980 - 31 August 1981
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John G. Woods		8. CONTRACT OR GRANT NUMBER(s) N00173-80-C-0238
9. PERFORMING ORGANIZATION NAME AND ADDRESS TRW, Inc. Electronic Components Group Research & Development Laboratories 401 N. Broad St., Philadelphia, Pa. 19108		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Research Laboratory 4555 Overlook Avenue, SW Washington, D.C. 20375		12. REPORT DATE December, 1981
		13. NUMBER OF PAGES 38
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Same as Block 11.		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

connector	demountable connector
fiber optic	single mode connector
single mode	fiber optic connector

microns

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A single mode fiber optic connector, suitable for making demountable connections with 80 µm diameter optical fibers, has been developed, constructed and tested. The connector uses the four-rod double elbow glass alignment guide principle, previously developed for multimode single fiber connections.

The single mode fiber requires an alignment guide with a smaller internal cusp than does the multimode guide. To obtain the 1.0 dB insertion

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loss with the approximately 4 μm diameter single mode core, a liquid filled guide and plastic reservoir system were developed. The TRW/Cinch cylindrical connector package (Optalign(R)) is used, with some modifications, to house the single mode guide and reservoir. The means for stripping, scribing and cleaving the single mode fiber are described, including the specially designed scribing machine.

In addition to the connector principles, development and construction work, this report describes the results of tests for insertion loss, temperature cycle, repeated matings and vibration.

PREFACE

This final report describes the work done on the development of a single mode optical fiber connector, performed for the Naval Research Laboratory, Washington, D.C., under contract number N 00173-80-C-0238, by TRW, Inc., Electronic Components Group, Research and Development Laboratories.

The alignment guide principle was invented by Malcolm H. Hodge, Ph.D. The reservoir for the index matching fluid is based on an invention by James F. Ryley, Jr. The connector package is the Optalign (R) connector construction developed under the direction of Edwin Rowlands of TRW/Cinch Connectors Division, Elk Grove Village, Illinois.

Other TRW personnel who have made significantcontributions to the single mode connector are: Joseph F. Larkin, for mechanical design; Morris Maynard and Robert Hamilton for preparation of the test setups and connector testing.

Support and guidance for this project were provided by Mr. Carl Villarruel and Dr. William Burns of the Naval Research Laboratory.

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1.0 INTRODUCTION

The objective of the single mode optical fiber connector program is to develop, test and deliver 25 demountable connectors for 80 μm diameter single mode fiber, with approximately 4 μm diameter cores. Since the core alignment is obtained by aligning the outside surfaces of the silica fiber ends, it is necessary that the fiber itself be made with a high degree of precision, particularly in regard to the concentricity of the core to the outside surface. The results obtained in this program with a v-groove alignment, and index matching fluid at the connection interface indicate that single mode fiber is currently available with the required precision.

The performance goals for the program are:

a. Connectors are to have interchangeable parts.

b. Insertion loss is to be less than 1.0 dB.

c. Insertion loss shall not increase above 1.0 dB after 50 connect-disconnect cycles.

d. The connector will be subjected to temperature cycling and vibration without appreciable effect on insertion loss.

This report includes discussions of the alignment guide and connector principles, the index matching fluid reservoir design, the development work accomplished and the results of performance and environmental tests.

2.0 BACKGROUND

During the past few years, TRW has developed a unique approach to the connection of single optical fibers, utilizing a patented four rod glass alignment guide, which has been described in detail in earlier papers [1,2]. Up to the time of the present contract, the development and evaluation effort has been devoted to multimode fiber connection. The same principles are used for the single mode fiber connector. A brief description of the alignment guide principle is given below, as background information.

2.1 THE ALIGNMENT GUIDE

The TRW patented four rod glass alignment guide[3] can be described as a ferrule/v-groove device, which provides a loose fitting channel to guide the fibers into an alignment v-groove. Figure 1 is a schematic diagram showing the principle of the fiber alignment guide. The two fibers are fed into the ends of the guide, and forced toward the top cusp by the double elbow configuration. The geometry of the guide is such that normal tolerances of molded or machined parts achieve sufficient locational accuracy of the fiber ends to prevent angular or gap losses in the fiber connection.

It was necessary, in the course of the work on this contract, to develop the guide dimensions for 80 μm diameter precision single mode fiber. Previous work had been devoted to the development of guides for 125 to 140 μm diameter multimode fibers.

TRW FIBER ALIGNMENT GUIDE

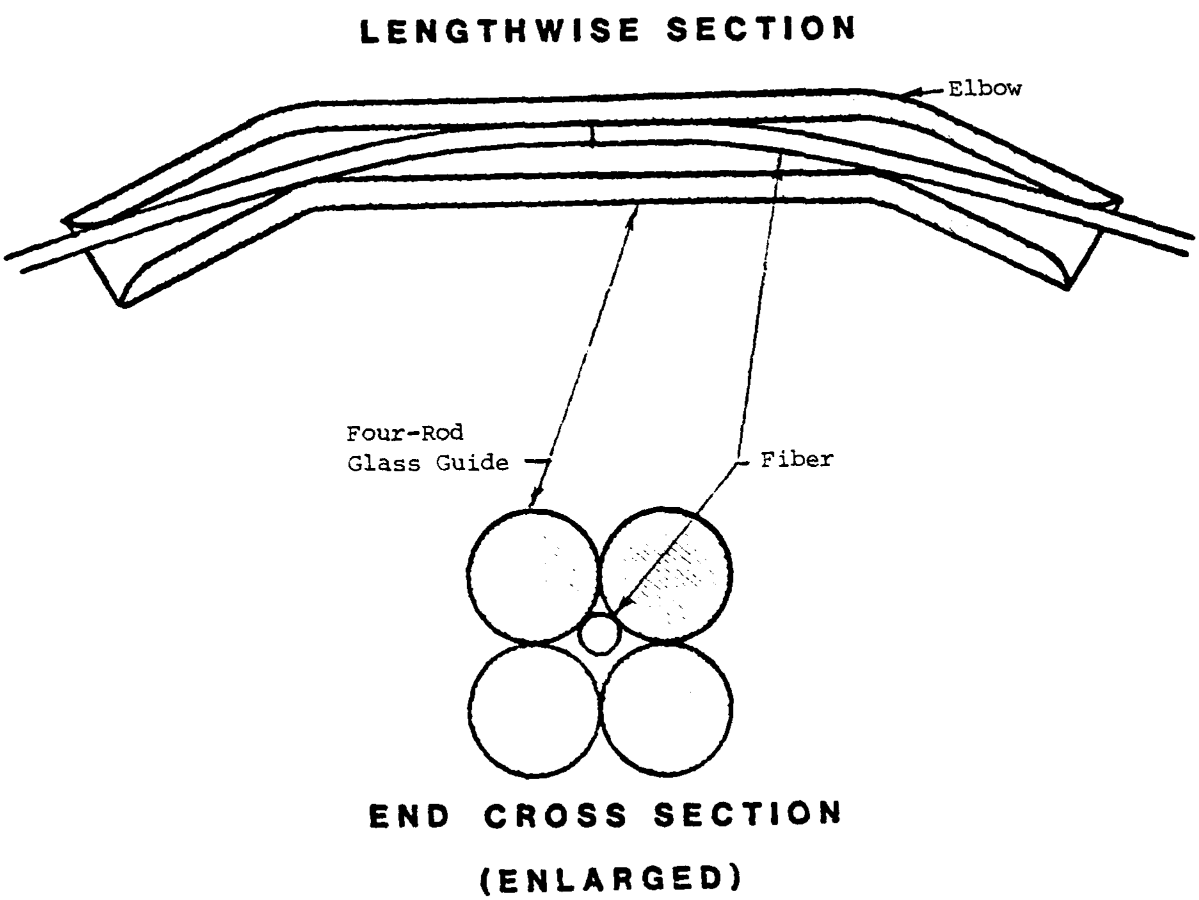


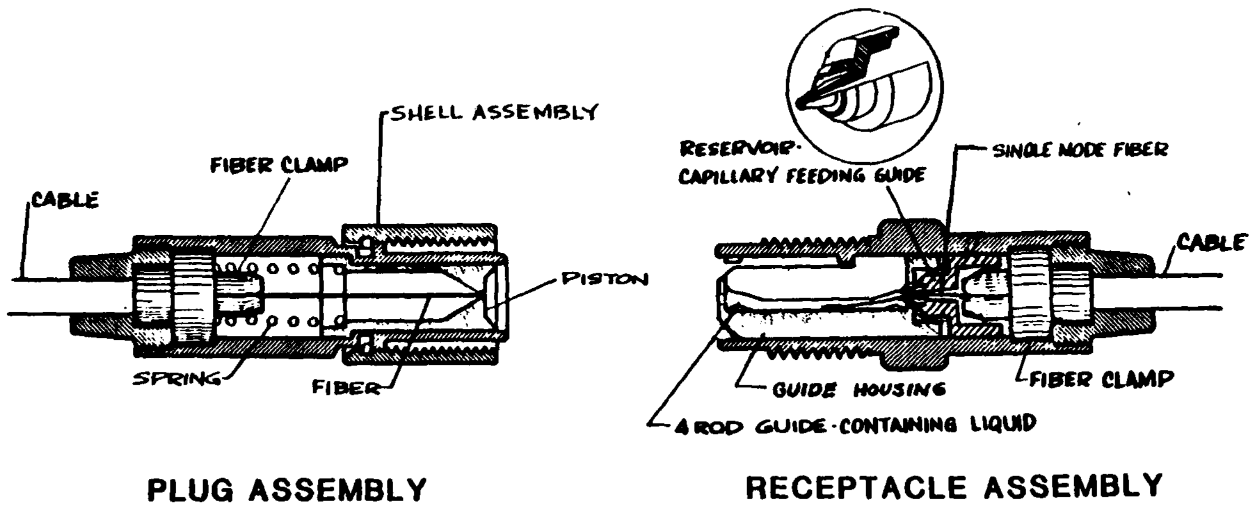
Figure 1

3.0 THE SINGLE MODE CONNECTOR

3.1 THE OPTALIGN (R) PRINCIPLE

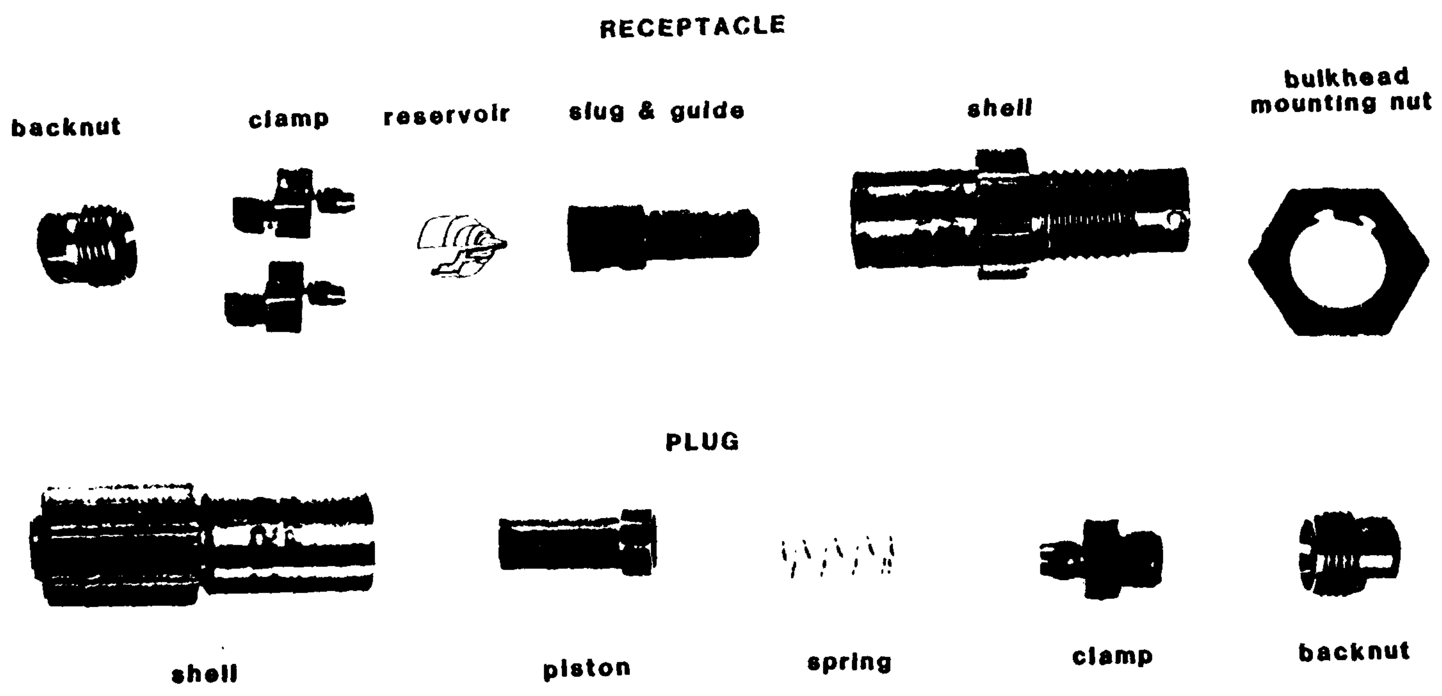
The single channel, single mode connector incorporates the four rod alignment guide in the TRW/Cinch Optalign (R) connector shell. Figure 2 is a cross-sectional drawing of the connector. Figures 3 and 4 are photographs of the unassembled and assembled connector, respectively. The alignment guide is enclosed in an injection molded plastic housing, or slug. The fibers are held in plastic fiber clamps in both the plug and in the receptacle. The clamps are retained by aluminum alloy nuts. The plug assembly contains a molded plastic piston, which slides in the aluminum shell, and is spring loaded to protect the fiber end until the guide slug pushes it back as the connector is mated. Upon mating of the connector, the fiber in the plug enters the end of the four rod guide in the receptacle. As the coupling nut is rotated to pull the two shell halves together, the fiber moves through the guide channel and is forced along the same v-groove, or cusp, in which the receptacle fiber end lies. The two fiber ends meet near the center of the four rod guide. To assure physical contact of the fiber ends, for minimum loss, an overtravel of .025mm (.001 in.) to .254mm (.010 in.) is allowed. The resulting bend in the fiber serves to relieve the stress and maintain low constant pressure at the fiber junction. The overtravel range is controlled by proper dimensioning and minimizing tolerance buildup between the faces of the fiber clamps. The fibers are cleaved to $\pm$ .076mm ($\pm$.003 in.) of their nominal length from the fiber clamp faces.

The assembly procedures were developed for multimode fibers; those operations applicable to single mode connection are included in Appendix C.



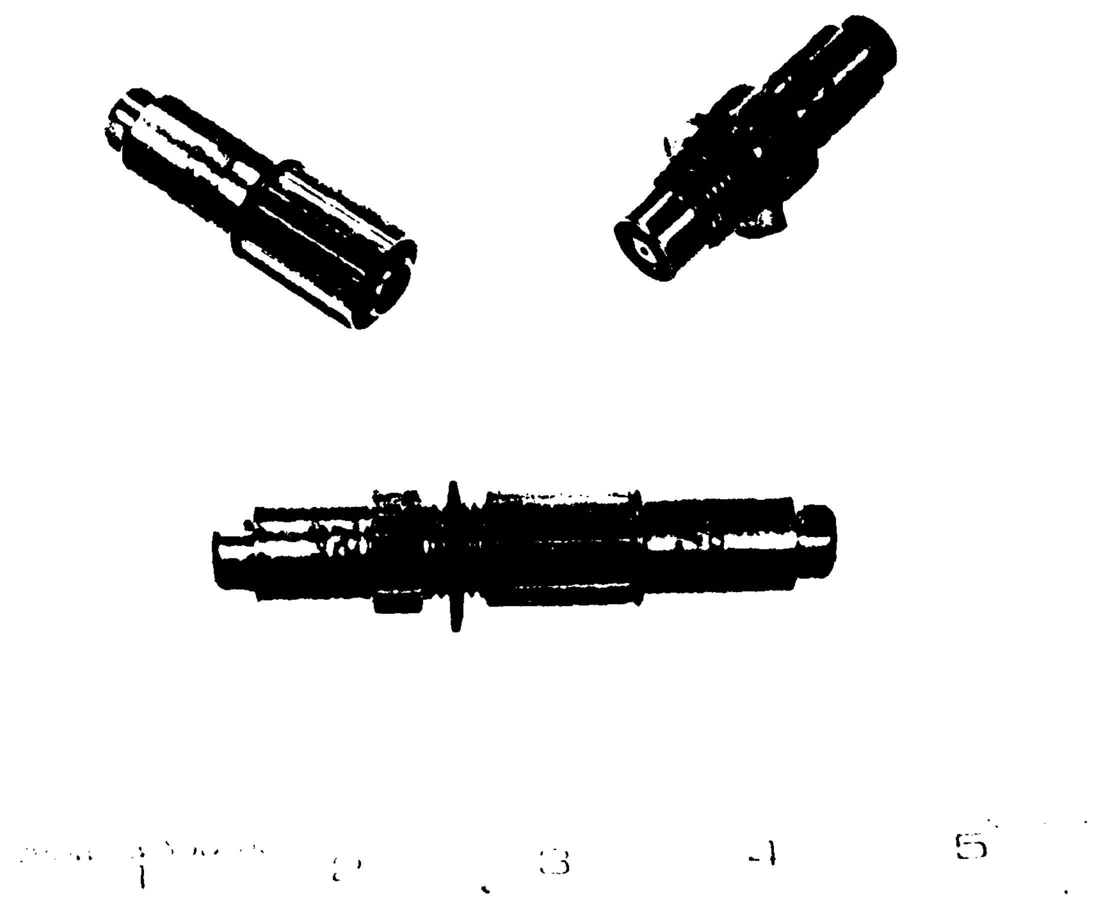
SINGLE MODE FIBER CONNECTOR

FIGURE 2



SINGLE MODE CONNECTOR - UNASSEMBLED

figure 3



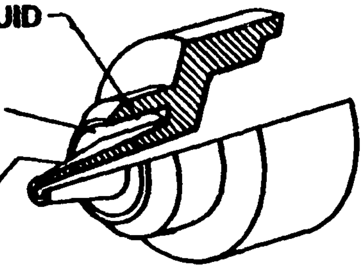
SINGLE MODE CONNECTOR – ASSEMBLED

figure 4

3.2 THE FLUID RESERVOIR

A recently presented paper described the application of the index matching fluid and reservoir to the alignment guide for single mode connections[4]. The invention of the reservoir occurred prior to the present contract. The design and development of a manufacturable reservoir was part of the work accomplished under the contract. Figure 2 shows the location of the injection molded plastic reservoir in the single mode connector. A sketch of the reservoir is shown in Figure 5. The index matching fluid is stored in an annular cavity and transported to the nose of the reservoir by capillary action in three v-shaped grooves. The fluid is carried between the fiber and alignment guide flare into the guide cusps, filling the guide to the opposite end.

As the connector is connected and disconnected, some of the fluid adheres to the fiber in the plug side, and may be partially lost. The reservoir provides the make-up fluid to compensate for any such loss.



INDEX MATCHING FLUID RESERVOIR

FIGURE 5

4.0 DEVELOPMENT OF THE SINGLE MODE CONNECTOR

The single mode connector required development work on: (1) the alignment guide, to obtain the proper dimensions for alignment of the 80 μm diameter fiber; (2) the molded reservoir design and fluid selection for index matching; and (3) preparation of the fiber ends, including stripping, cleaning, scribing and cleaving the single mode fibers. The following paragraphs summarize the work performed in these areas.

4.1 ALIGNMENT GUIDE DEVELOPMENT

The principle of the alignment guide is described in paragraph 2.1, above. A computer program has been designed to calculate the guide dimensions to axially align fibers of any given diameter.

Figure 6 shows the variables involved in the guide dimensions which, along with the fiber diameter, are identified as affecting the distance the fiber is on axis before it meets the mating fiber at the center of the guide. The guide elbow bend causes the fiber to bend at the radius, R_C. Increasing the angle (Θ) of the bend causes a longer length of fiber to be on axis. Too great an angle would make it difficult to insert the fiber in the guide, especially in the case of single mode (80 μm) fiber, which is less rigid under compressive load than is the typical (125 μm) multimode fiber.

A computer program has been developed to aid in optimizing the conditions for given fiber diameters. The program is based on beam deflection formulas applied to the fiber. Appendix A shows a printout of the variables for .00315 in. (80 μm) fiber; X and Y dimensions of .100 in. (2.54mm) and .200 in. (5.08mm), respectively; and guide angle (Θ) of 6.0 to 8.0 degrees.

The desirable conditions are a zero degree fiber angle in the Y section of the guide and a sufficient "distance of fiber on axis" to allow for axial

tolerances in the position of the fiber contact plane. A 7.0 to 7.5 degree guide angle, and cusp diameter of .0052 to .0057 inch (.132 to .145mm) cause an on-axis distance for each fiber of .070 to .138 inch (1.778 to 3.505mm). Large guide angles, or smaller cusp diameters, impose smaller bend radii in the fiber and make fiber insertion into the guide more difficult. Larger cusp diameters, or smaller guide angles, provide little or no on-axis distance, which could cause the fiber faces to be non-parallel.

The across-flats dimension can be seen to be .025 to .028 inch (.635 to .711mm) for the selected conditions in Appendix A. This dimension is the calculated dimension outside the guide, as shown in Figure 6, assuming no fusion at the interfaces of the four rods. In experimenting with guides of this dimension, it was found that the guides are difficult to flare consistently due to the weak, small area cross-sections. The standard guides for 125 μm multi-mode fibers are .040 to .044 inch (1.016 to 1.175mm) across flats, which are stronger and can be flared more uniformly than the smaller guides. We decided to develop a procedure to use the .040 to .044 inch standard guide stock by modifying the firing conditions of the forming operation.

The guides are made by first drawing the four-rod preform to a controlled across-flats size and cusp diameter. The guide stock is cut to .750 inch (19.05mm) lengths, flared with a heated tool and then fired in a nitrogen atmosphere in a graphite boat to form the two bends. It was found that increasing the firing temperature and/or the length of time in the conveyor kiln reduces the cusp diameter, with only slight reduction of the across-flats dimension. By using a firing temperature of 900°C, with a 30 minute total cycle time through the conveyor kiln, the cusp diameter was decreased to the desired .0052 to .0057 inch diameter.

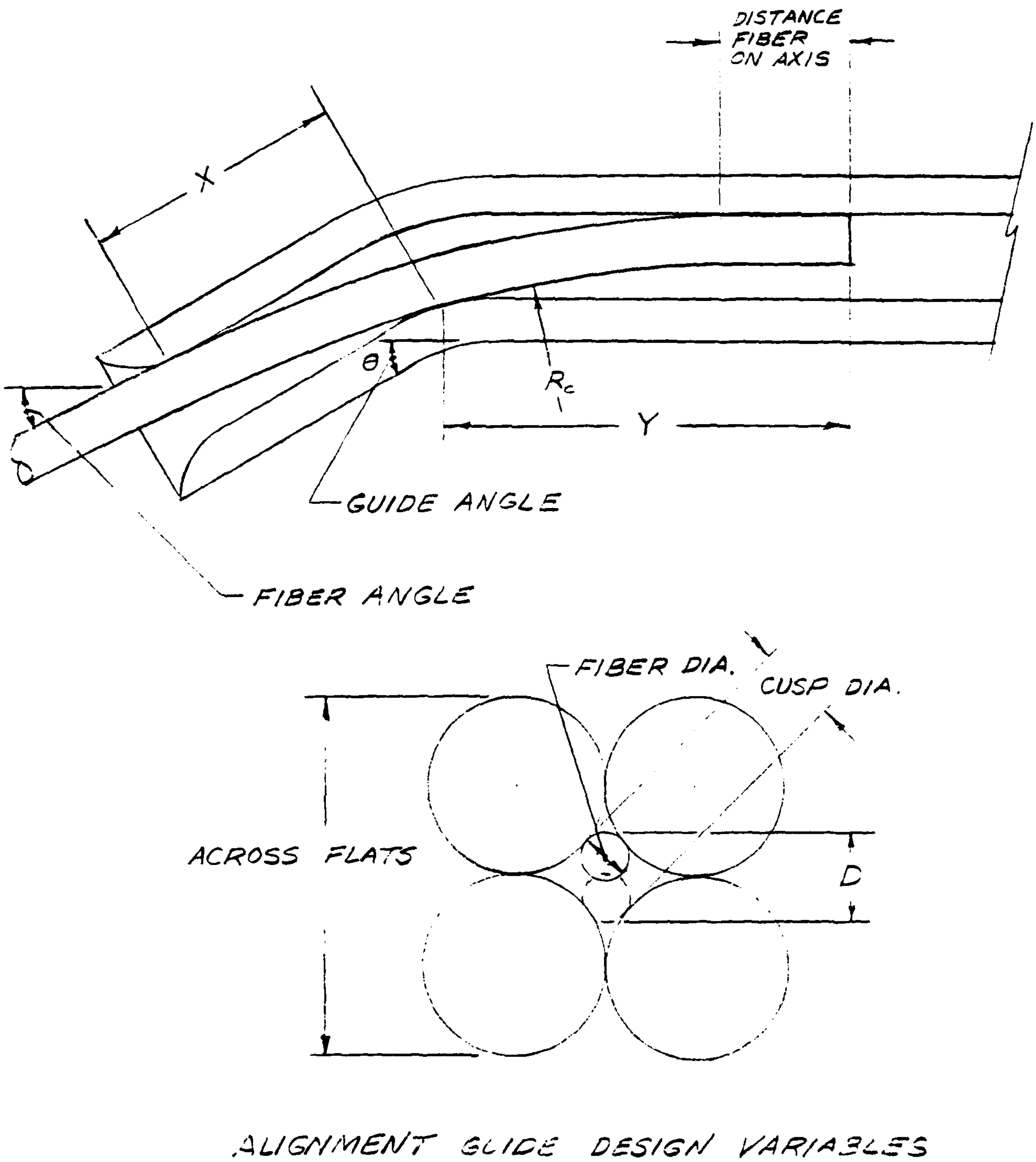

DISTANCE
FIBER
ON AXIS
X
θ
R_c
Y
GUIDE ANGLE
FIBER ANGLE
FIBER DIA.
CUSP DIA.
ACROSS FLATS
D
ALIGNMENT GUIDE DESIGN VARIABLES

FIGURE 6

4.2 RESERVOIR DEVELOPMENT

The reservoir designed for this contract is shown in Figure 7, which is a reduced detail drawing of the part. The overall dimensions were chosen to fit in the standard Optalign$^{(R)}$ connector shell when a portion of the guide slug is removed. The configuration of the .118 inch (3.0mm) deep annular reservoir cavity and the 60 degree capillary feed grooves were modeled after the original drawn glass version, modified for plastic injection molding. When assembling a connector receptacle, the fiber is fed into the 60° x .090 inch (2.29mm) funnel, and through the .010 inch (.254mm) hole, into the alignment guide.

A single cavity injection mold was built to produce the designed reservoir. Clear polycarbonate was chosen as the material for the part, based on its surface characteristics and moldability.

It was originally thought that the nose of the reservoir should be forced in contact with the guide flare to properly feed the fluid into the guide. The contact was maintained by a coil spring between the reservoir and fiber clamp (see Figure 2). Experiments with the complete connector showed that intimate contact was not necessary for fluid transport, and the coil spring was eliminated. A shim was inserted between the slug and reservoir to take up most of the clearance. Later, the shim was designed out by lengthening the slug.

An experiment was performed to observe the function of the system, as fiber is drawn through a fluid-filled reservoir and alignment guide. The fiber was pulled at a constant speed by a motor driven drum. A microscope was set up to aid in observing the fluid in the guide. The fluid chosen for index matching is Dow Corning #200 silicone fluid; 100 centistokes viscosity. For this ex-

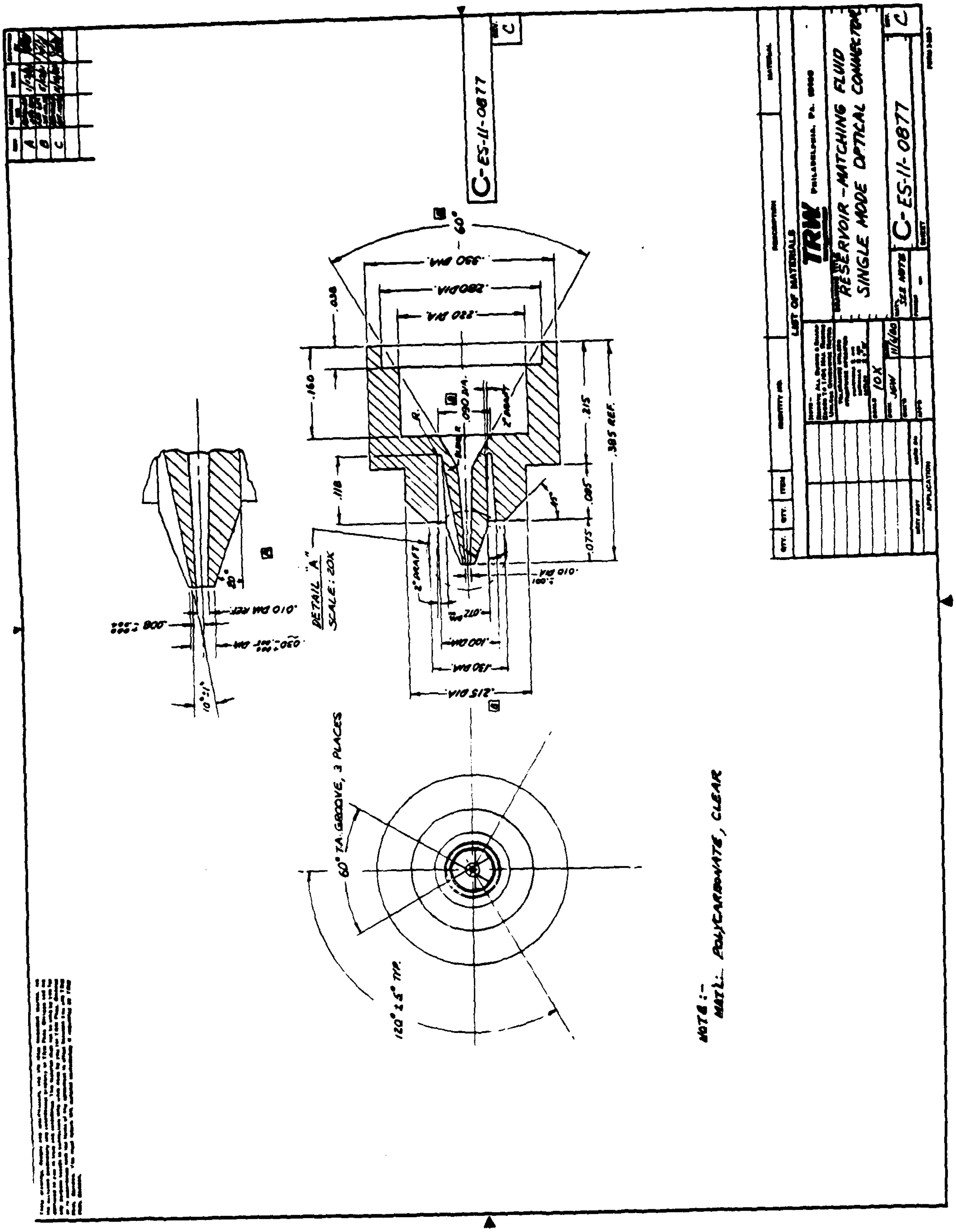

C-ES-11-0877
TRW
PHILADELPHIA, PA.
RESERVOIR-MATCHING FLUID
SINGLE MODE OPTICAL CONNECTOR
LIST OF MATERIALS
DETAIL "A"
SCALE: 20X
60° T.A. GROOVE, 3 PLACES
120° ± 5° TYP.
NOTE:-
MAT'L: POLYCARBONATE, CLEAR

FIGURE 7

periment, the fluid was dyed blue to make it more visible in the transparent reservoir and guide.

The reservoir and guide system functioned as designed. As the fiber was drawn through the guide at the rate of 3 inches (76.2mm) per minute, the dyed fluid moved from the reservoir annulus through the guide. 32 inches (81.3 cm) of fiber were drawn through the guide before discontinuities in the fluid flow were observed. This corresponds to the total length of fiber that would be inserted and withdrawn in 100 matings of a connector, using dry fiber for each insertion.

Because of the excellent results obtained with the injection molded part of Figure 7, the polycarbonate material and the 100 cs silicone fluid, this system was used in the final models.

4.3 PREPARATION OF FIBER ENDS

Development of the methods for stripping of the protective Hytrel jacket, as well as for scribing and cleaving of the fibers, required considerable experimental work. The fiber used for this work was the ITT Type T-1601 single mode optical fiber, as described in the ITT literature (see Appendix B). Small samples of precision fiber were received from the Naval Research Laboratory; sufficient to indicate that the procedures developed for the T-1601 would be applicable to ITT, precision fiber.

4.3.1 Stripping of Jacket and Buffer

As shown in the cross-sectional drawing of Appendix B, page B-2, the ITT single mode fiber has a Hytrel outer jacket as well as an inner jacket, or buffer, of RTV silicone. Both jackets must be removed from the portion of the fiber which is to be inserted into the alignment guide. This is to ensure good

alignment of the outer surface of the silica fiber in the guide's v-groove.

Generally, the Hytrel jacket and most of the buffer layer can be removed by first skimming the jacket with a sharp blade, such as a razor blade. The jacket end is then made even with a .010 no-nik wire stripper. The stripped portion is made long enough (about 2¼") to provide for the succeeding clamping and scribing operations. See Assembly Procedure, Appendix C.

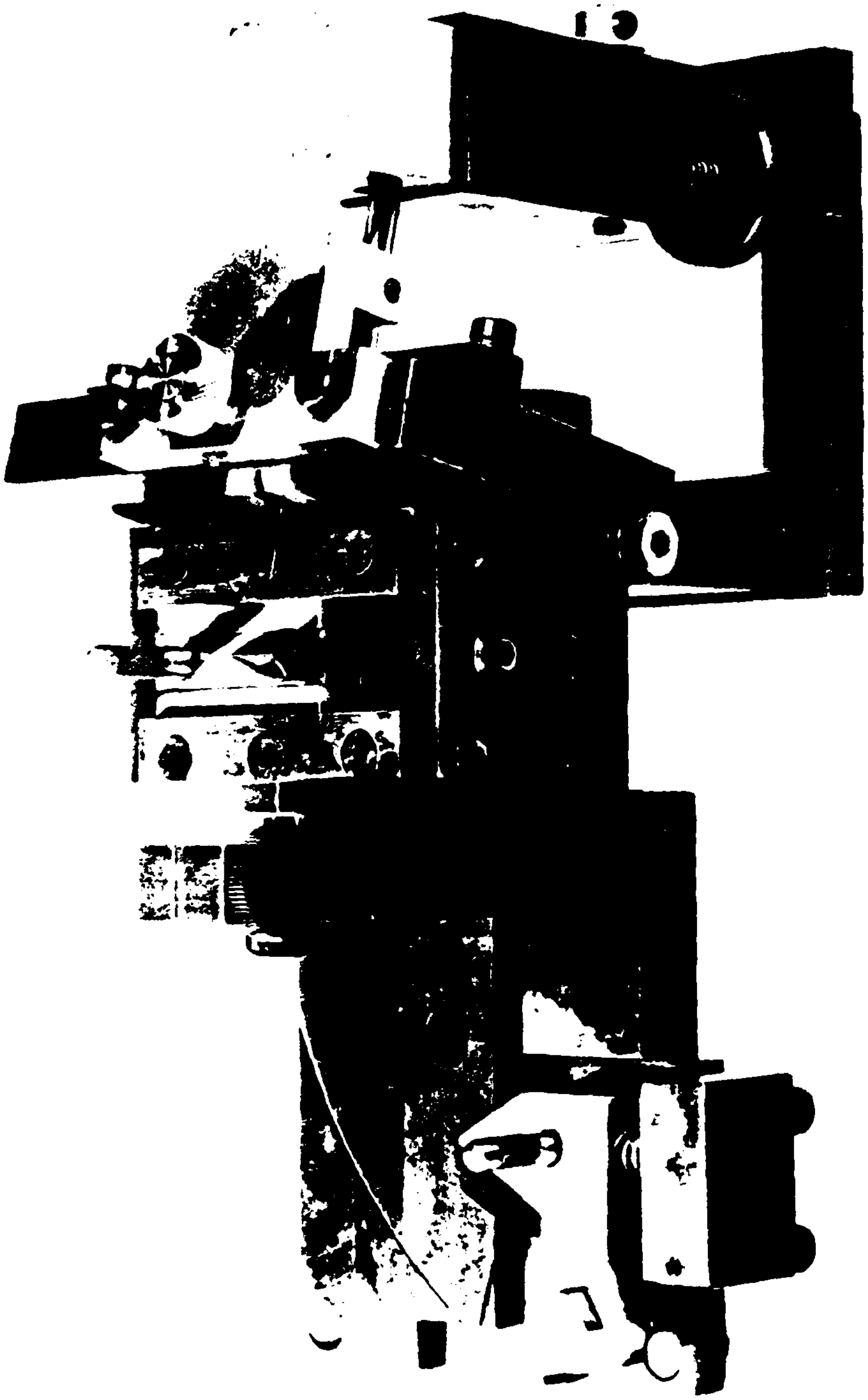
It has been found necessary, with some samples of jacketed fiber, to use a chemical stripper (such as Cee Bee #105 HF, McGean Chemical Co., Downey, CA) to remove the last vestiges of silicone from the fiber.

The removal of the silicone buffer layer from the silica fiber will cause loss in fiber strength upon exposure to normal levels of moisture in the air. To prevent this loss, we have developed a simple procedure to dip-coat the exposed fiber in trimethylchlorosilane. The silane compound forms a monomolecular layer, chemically bonded to the glass surface. The coating effectively seals against moisture attack, but has no effect on fiber diameter, or concentricity of the core to outside diameter. Thus, there is no adverse effect on insertion loss due to the silane coating.

4.3.2 Scribing and Cleaving

Our previous work had shown the proportionality of insertion loss to fiber end angle[2]. In addition, the angle of the cleave was found to be directly proportional to the fiber twist angle applied during cleaving[2,5]. These findings demonstrated the importance of imparting minimal torsion to the fiber during cleaving.

A scribing/cleaving machine (Figure 8) was designed and built, based on the earlier multimode laboratory scribers, used for 125 μm diameter fiber. The fiber clamp was designed to impart no torsion to the fiber. A dual loading



SCRIBING/CLEAVING MACHINE

figure 8

device also ensures that the cleaving does not occur when the scribing blade scrapes the fiber, which would cause a slight torsion.

The amount of axial preload applied during scribing, and the axial breaking load to cleave the scribed fiber were calculated, based on the loads used for multimode fibers. The preload for 80 μm single mode fiber is 33 grams and the breaking load is 74 grams. The calculated tensile stresses are 60 Mn/m^2 and 145 Mn/m^2, respectively.

The scribing/cleaving machine built for the single mode fiber consistently produces cleaved ends within 2 degrees of a plane perpendicular to the fiber axis. The ends also have a mirror finish in the core area caused by the controlled breaking load.

The procedure for operating the scriber/cleaver is described as part of the connector assembly procedure in Appendix C.

5.0 CONNECTOR PERFORMANCE

Connectors were assembled using the procedures described above. Performance and environmental tests included: insertion loss; temperature cycle; repeated matings; and vibration

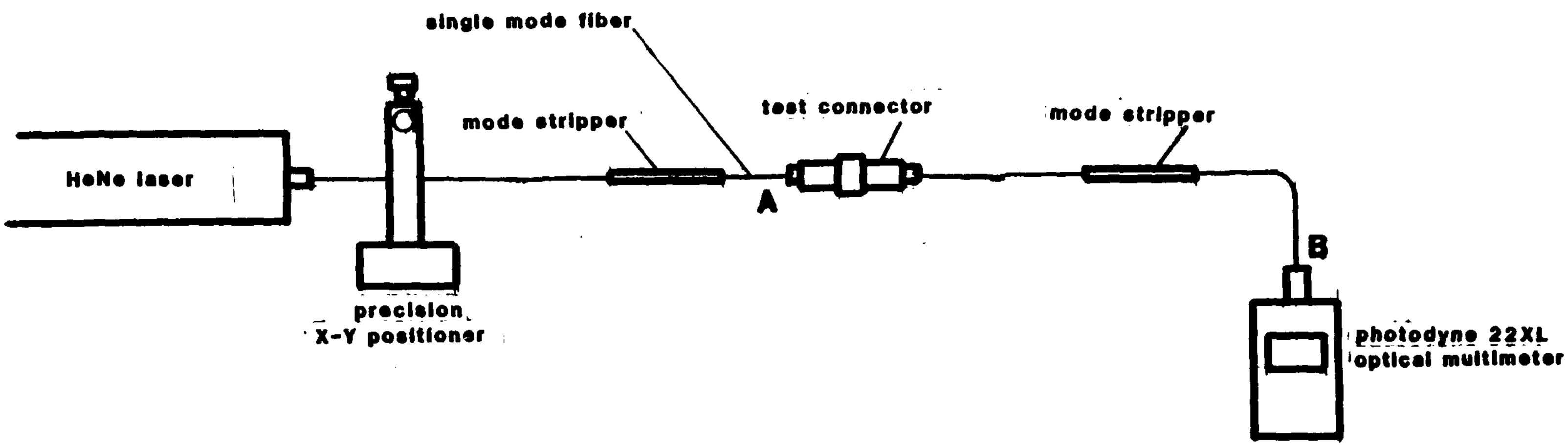
5.1 INSERTION LOSS

Insertion loss was measured using the test set-up shown in Figure 9. The helium-neon laser (λ=632.8 nm) launches light into the single mode fiber, which is clamped in a precision x-y positioner. The light passes through a cladding mode stripper, through the connector being tested, through a second cladding mode stripper and on to a PIN diode matched to the optical multimeter. The multimeter reads optical power directly in dBm or dBμ.

The basic test procedure for measurement of insertion loss is to use the multimeter to measure the light coming from the fiber at point "A" before assembling the connector and then measuring the light at point "B" after the connector is inserted. The insertion loss in dB is: $dB\mu_A - dB\mu_B$. In some instances, we have used a power meter, which displays microwatts of optical power (P). When this is used, the insertion loss is calculated:

$$\text{dB loss} = 10 \log_{10} \frac{P_A}{P_B}$$

When performing the insertion loss test, during measurement of power at point "A", the x-y positioner is manipulated to obtain maximum power, as indicated by the optical meter. It was found that this adjustment must be made each time, as there is a long term downward drift, which can be as much as 1.0 dB in an hour. Readjustment of the position gererally returns the power to its



INSERTION LOSS TEST SETUP

figure 9

original level. A short term variation in power is also observed when using the laser as the light source. This variation can be as much as $\pm$ 0.6 dB over a few minutes.

Typical insertion loss readings are shown in Table IA. These are the values obtained for the 25 connectors delivered to NRL, with 1.1 dB shown as typical of the group. It should be remembered that the T-1601 fiber was used, rather than fiber of guaranteed precison. When the connectors were delivered to NRL, a randomly selected connector had an insertion loss of 0.1 to 0.2 dB, using precision single mode fiber.

5.2 TEMPERATURE CYCLE

The temperature cycle test was performed according to MIL-STD-202E, Method 107D, Condition A; 5 cycles, -55°, 25°, 85°, 25°C.

Measurements of insertion loss were made at each temperature level for the five cycles. Loss, in dB, is plotted for the 16 readings in Figure 10. The initial 25°C reading was 0.42 dB; final was 0.72 dB, which was also the maximum. The slight upward drift was probably related to mode changes in the laser light launched into the fiber.

5.3 REPEATED MATINGS

An assembled connector was subjected to 50 connect/disconnect cycles. See Table IB. The effect of the repeated matings on insertion loss was negligible, indicating that there was no damage to fibers or connector and that the matching fluid system worked throughout the test.

5.4 VIBRATION

The vibration test was performed according to MIL-STD-202E, Method 204C, Condition A. The test involves mounting the connector in three orthogonal

TABLE I

A. INSERTION LOSS

25 CONNECTORS,	TYPICAL	1.1 dB
	MAXIMUM	1.6 dB
	MINIMUM	0.3 dB

B. REPEATED MATINGS

INITIAL INSERTION LOSS,	0.9 dB
LOSS AFTER 50 MATING CYCLES,	0.8 dB

EFFECT OF TEMPERATURE CYCLE ON INSERTION LOSS

SINGLE MODE CONNECTOR

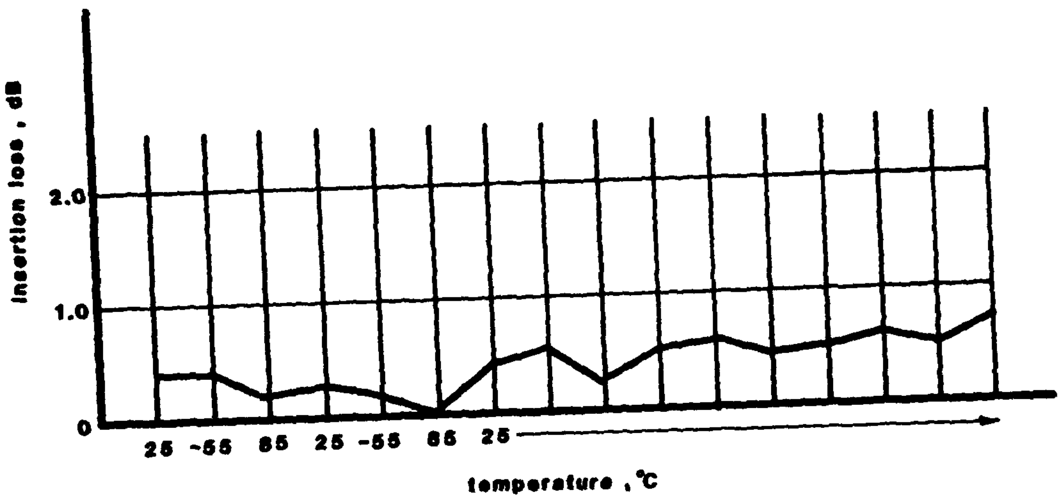


FIGURE 10

EFFECT OF VIBRATION ON INSERTION LOSS

SINGLE MODE CONNECTOR

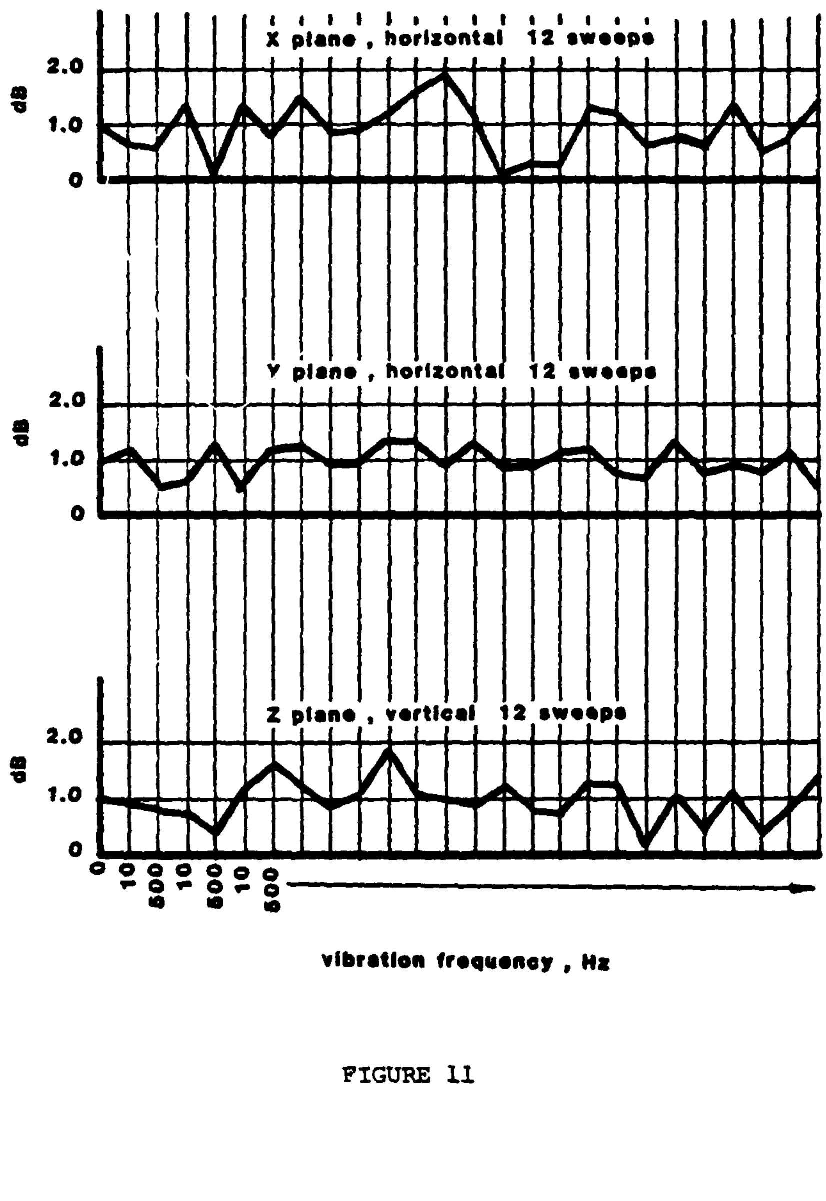


FIGURE 11

planes, and sweeping from 10 to 500 Hz, 10g maximum.

Insertion loss was monitored while the connector was on the vibration machine. Loss variations are plotted for 25 readings at the high and low frequency extremes in Figure 11. The plots have been adjusted to compensate for the laser-to-fiber drift, which was correctable with the precision x-y fiber positioner after each run.

The short term variations in loss during the vibration test, as shown on the graphs, was found to occur whether or not the vibration machine was operating. These fluctuations appear to be related to the laser output pattern changes sensed by the small fiber, and are unrelated to the connector. Vibration had negligible effect on the connector, or on light throughput.

6.0 CONCLUSIONS

1. The single mode connector provides typical insertion losses of 1.1 dB, with ITT Type T-1601 single mode fiber.

2. Lower losses, well under 1.0 dB, have been obtained with limited tests of 80μm diameter precision fiber.

3. The index matching fluid and the four rod alignment guide provide the means for low loss single mode connections.

4. The molded plastic reservoir performs the function of replenishing the index matching fluid during repeated matings.

5. The single mode connection is essentially unaffected by vibration and temperature cycle, as tested in this project.

7.0 RECOMMENDATIONS

1. Fiber strength, in the jacketed or stripped condition, would be enhanced if fiber manufacturers were to coat the silica fiber with silane or silane/silicone prior to applying the buffer layer.

2. Further work would be desirable to design alignment guides for smaller diameter fibers (e.g. 70μm, now being used at NRL).

3. A useful feature for loss optimization, suggested by Carl Villarruel of NRL, would be to provide means for angular adjustment of one fiber, relative to the other fiber in the connector for elliptical core fiber. The feasibility of incorporating this feature in the connector should be explored.

REFERENCES

1. Hodge, Malcolm H., "A Low Loss Single Fiber Connector Alignment Guide", Fiber Optic Conference, 1978, Proceedings, pp 111-115.

2. Woods, John G.; Hodge, Malcolm H.; Ryley, James F., Jr., " A Military Six Fiber Hermaphroditic Connector", Fiber Optic Conference, 1980.

3. U.S. Patent No. 4,192,575, "Guide-Connector Assembly for Joining Optical Fibers and Method of Making Guide Therefor", M.H. Hodge, Assignor to TRW, Inc.

4. Ryley, J.F., Jr.; Woods, J.G.; Hodge, M.H., "An Index Matching Single Mode Fiber Alignment System", International Electrical and Electronics Conference, October 5-7, 1981, Toronto, Canada.

5. Saunders, M.J., "Torsion Effects on Fractured Fiber Ends", Applied Optics, Vol. 18, No. 10, 15 May 1979.

APPENDIX A

80μm Alignment Guide Design

GUIDE ANGLE	D	X	Y	FIBER ANGLE AT Y	DIST. FIBER ON AXIS	FIBER ANGLE OUT FLARE	CUSP DIA.	FIBER DIA.	ACROSS FLATS
6.00	.0030	.100	.200	0.0000	0.0989	4.8539	.0052	.0032	.025
6.00	.0032	.100	.200	0.0000	0.0779	4.7103	.0054	.0032	.026
6.00	.0034	.100	.200	0.0000	0.0449	4.5668	.0055	.0032	.026
6.00	.0036	.100	.200	0.0605	0.0000	4.4233	.0056	.0032	.027
6.00	.0038	.100	.200	0.1753	0.0000	4.2797	.0057	.0032	.028
6.00	.0040	.100	.200	0.2900	0.0000	4.1362	.0059	.0032	.028
6.00	.0042	.100	.200	0.4048	0.0000	3.9927	.0060	.0032	.029
6.00	.0044	.100	.200	0.5196	0.0000	3.8491	.0061	.0032	.030
6.00	.0046	.100	.200	0.6343	0.0000	3.7056	.0062	.0032	.030
6.00	.0048	.100	.200	0.7491	0.0000	3.5620	.0064	.0032	.031
6.00	.0050	.100	.200	0.8639	0.0000	3.4185	.0065	.0032	.031
6.00	.0052	.100	.200	0.9786	0.0000	3.2750	.0065	.0032	.032
6.00	.0054	.100	.200	1.0934	0.0000	3.1314	.0067	.0032	.032
6.00	.0056	.100	.200	1.2082	0.0000	2.9879	.0068	.0032	.033
6.00	.0058	.100	.200	1.3229	0.0000	2.8444	.0070	.0032	.034
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6.00	.0062	.100	.200	1.5525	0.0000	2.5573	.0072	.0032	.035
6.00	.0064	.100	.200	1.6672	0.0000	2.4137	.0073	.0032	.035
6.00	.0066	.100	.200	1.7820	0.0000	2.2702	.0074	.0032	.036
6.00	.0068	.100	.200	1.8968	0.0000	2.1267	.0075	.0032	.036
6.50	.0030	.100	.200	0.0000	0.1169	5.4383	.0052	.0032	.025
6.50	.0032	.100	.200	0.0000	0.1029	5.2947	.0054	.0032	.026
6.50	.0034	.100	.200	0.0000	0.0859	5.1511	.0055	.0032	.026
6.50	.0036	.100	.200	0.0000	0.0609	5.0075	.0056	.0032	.027
6.50	.0038	.100	.200	0.0077	0.0000	4.8640	.0057	.0032	.028
6.50	.0040	.100	.200	0.1225	0.0000	4.7204	.0059	.0032	.028
6.50	.0042	.100	.200	0.2373	0.0000	4.5768	.0060	.0032	.029
6.50	.0044	.100	.200	0.3521	0.0000	4.4332	.0061	.0032	.030
6.50	.0046	.100	.200	0.4669	0.0000	4.2896	.0062	.0032	.030
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6.50	.0050	.100	.200	0.6965	0.0000	4.0024	.0065	.0032	.031
6.50	.0052	.100	.200	0.8113	0.0000	3.8588	.0065	.0032	.032
6.50	.0054	.100	.200	0.9261	0.0000	3.7152	.0067	.0032	.032
6.50	.0056	.100	.200	1.0409	0.0000	3.5717	.0068	.0032	.033
6.50	.0058	.100	.200	1.1557	0.0000	3.4281	.0070	.0032	.034
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6.50	.0064	.100	.200	1.5001	0.0000	2.9973	.0073	.0032	.035
6.50	.0066	.100	.200	1.6149	0.0000	2.8537	.0074	.0032	.036
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7.00	.0030	.100	.200	0.0000	0.1289	6.0230	.0052	.0032	.025
7.00	.0032	.100	.200	0.0000	0.1189	5.8794	.0054	.0032	.026
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7.50	.0056	.100	.200	0.7059	0.0000	4.7398	.0068	.0032	.033
7.50	.0058	.100	.200	0.8207	0.0000	4.5961	.0070	.0032	.034
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7.50	.0062	.100	.200	1.0505	0.0000	4.3087	.0072	.0032	.035
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7.50	.0066	.100	.200	1.2802	0.0000	4.0213	.0074	.0032	.036
7.50	.0068	.100	.200	1.3951	0.0000	3.8776	.0075	.0032	.036
8.00	.0030	.100	.200	0.0000	0.1449	7.1933	.0052	.0032	.025
8.00	.0032	.100	.200	0.0000	0.1379	7.0495	.0054	.0032	.026
8.00	.0034	.100	.200	0.0000	0.1299	6.9057	.0055	.0032	.026
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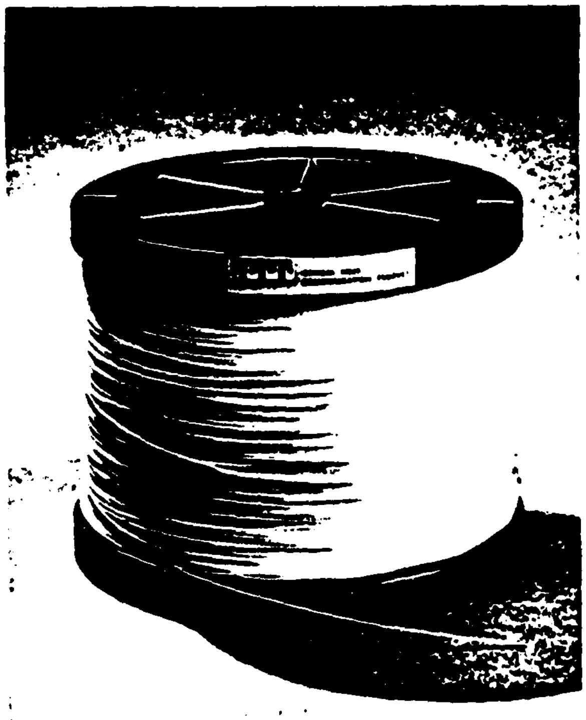
8.00	.0068	.100	.200	1.2275	0.0000	4.4616	.0075	.0032	.036

SINGLE MODE OPTICAL FIBER

Single Mode Optical Fiber, Type T-1601, is designed for use in very high bandwidth (500 MHz or more) single fiber data transmission systems or in other applications which require single-mode propagation of light. The fiber consists of a doped silica core and a borosilicate cladding with a step-index profile. A plastic jacket (Hytrel™) is extruded onto the fiber to provide mechanical and environmental protection.

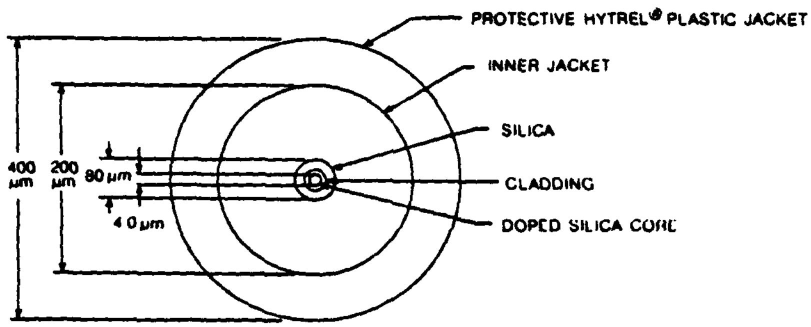


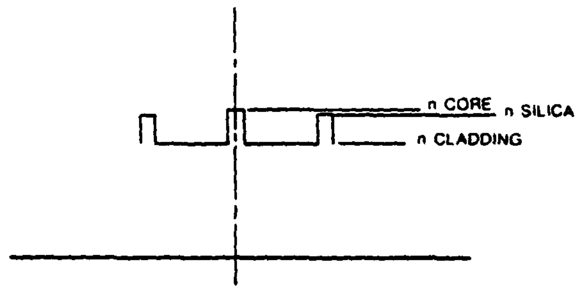
SPECIFICATIONS	NOMINAL
Attenuation	
@ .63 μm	10 dB/km
@ .85 μm	5 dB/km
Numerical Aperture	.11
Fiber Core Dia.	4.0 μm
Fiber Outer Dia.	80 μm
Jacket Outer Dia.	400 μm
Minimum Bend Radius	0.5 cm
Continuous Length Proof Test	25 kpsi (.25% Elongation)

ITT

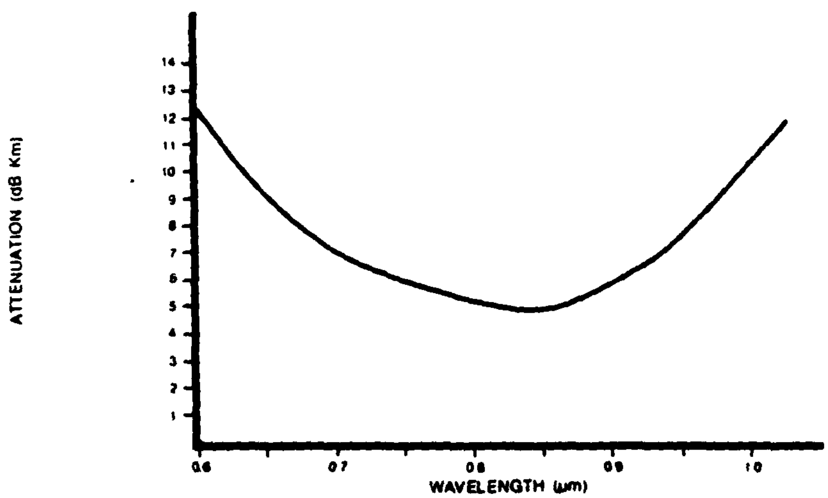
SINGLE MODE OPTICAL FIBER

DIMENSIONS SHOWN ARE NOMINAL VALUES





INDEX OF REFRACTION PROFILE



TYPICAL SPECTRAL ATTENUATION - SINGLE MODE OPTICAL FIBER

2/80

ELECTRO-OPTICAL PRODUCTS DIVISION ITT
7635 Plantation Rd., Roanoke, VA 24019. Telephone (703)563-0371

APPENDIX C

TRW ELECTRONIC COMPONENTS GROUP
RESEARCH AND DEVELOPMENT LABORATORIES
PHILADELPHIA, PENNSYLVANIA 19108

ASSEMBLY PROCEDURE
SINGLE MODE FIBER OPTIC CONNECTOR

I. Fiber End Preparation

A. Strip Hytrel jacket and silicone from fiber, 2½ inch from both ends to be connected.

1. Skim off jacket on one side with razor blade; peel remainder and cut off.
2. Use .010 No Nik wire stripper to trim off residual jacket material.
3. Immerse stripped end in silicone stripper 1 to 2 minutes, or until all silicone is removed. Wipe with Kimwipe.
4. Dip stripped end in trimethylchlorosilane, 2 minutes.

B. Assemble fibers in clamps; both ends.

1. Slide metal backnut over fiber.
2. Assemble 2 piece black plastic scissor clamp.
3. Slide clamp over fiber until Hytrel jacket protrudes 0.1 inch, maximum, beyond end of clamp.
4. Assemble clamp into backnut, keeping fiber centered in clamp.
5. Visually check to see that fiber is centered in clamp. If necessary, slide clamp out of backnut, adjust fiber and reassemble.

C. Prepare plug side (shell with coupling ring; spring loaded piston) for "no light" fiber.

1. Scribe and cleave fiber.

   a) Set scribing machine for "long" fiber length.

   b) Place clamp in threaded holder with clamp jaws horizontal, to ensure correct fiber height.

   c) Close holder and tighten bracket.

   d) Place fiber free end in yoke clamp.

   e) Position yoke against stop. Yoke should be slightly short of vertical.

   f) Tighten knurled clamp screw.

   g) Slide scribing blade under fiber, and return to original position. Observe that diamond blade touches the fiber.

   h) Gently release breaking weight. Break may occur in 0 to 15 seconds.

   i) If no break occurs, raise weight and rescribe. Repeat step h).

   j) Remove cleaved fiber/clamp/backnut assembly from holder.

   k) Examine fiber end for squareness and cleanliness, using 10X magnifier. Clean with acetone if necessary.

2. Assemble plug.

   a) Stand shell with front end down on clean surface.

   b) Drop piston into shell, making sure it bottoms against shoulder at front of shell.

c) Slip spring carefully over fiber onto the clamp nose. Make sure that fiber is centered and aligned in clamp.

d) Hold clamp/spring assembly with fiber end downward and carefully lower it into shell assembly.

e) Tighten the backnut finger tight,being careful not to tilt the nut when starting the threads. Do not tip the shell until the backnut has been tightened.

f) The fiber end should be just behind the front surface of the piston.

D. Prepare receptacle side (shell with external threads; alignment guide in slug) for "light side" fiber.

1. Scribe and cleave fiber.

a) Set scribing machine for "short" fiber length.

b) Follow steps C.1. b) through k), above.

2. Assemble receptacle.

a) Observe that glass alignment guide is positioned in plastic slug with flares centered at both end holes.

b) Drop slug into shell, making sure it bottoms against internal shoulder.

c) Place shell front end downward on a clean surface.

d) Drop in shim washer, making sure it is flat on the back of the slug.

e) Apply DC-200 silicone oil (100CS) in annular reservoir cavity, using a hypodermic needle.

f) Drop reservoir into shell, making sure it bottoms against the shim.

g) Examine fiber/clamp assembly to ensure that fiber is centered in clamp jaws.

h) Carefully insert fiber into shell assembly, feeding it through the reservoir capillary into the alignment guide.

i) Tighten the backnut finger tight, being careful not to tilt the nut when starting the threads. Do not tip the shell until the backnut has been tightened.

j) If fiber is carrying visible light, a light spot will be visible at the front of the slug, indicating proper positioning of the fiber in the guide.

3. Connect the two halves.

a) Insert the plug into the receptacle, with key and keyway aligned. The keyway may be tight at first.

b) Engage coupling nut with threads and tighten. Do not allow halves to spring apart.

c) To achieve optimal connection, do not reverse the direction of the coupling nut once engagement has begun. Disengage and start again if the coupling nut is accidentally reversed. Avoid twisting the shells together.

d) Connector assembly is completed.